Brazilian Pepper Task Force Members

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INTRODUCTION

Exotic pest plants are introduced either accidentally through shipping materials or deliberately for ornamental or commercial purposes. The aggressiveness common to some of these introduced species is often not recognized immediately. These invasive, exotic species disrupt native ecosystems with such intensity that natural systems can no longer function. The problems associated with foreign aquatic infestations are well documented. Water hyacinth (*Eichhornia crassipes*) is notorious for restricting navigation and reducing water abatement in flood control canals. Navigation has been the primary concern for federal and/or state-sponsored nuisance plant control efforts. Unfortunately, upland and wetland exotic plant management issues have been largely overlooked.

Without an organized forum to address invasive exotic plants in the State's natural areas, early control efforts were spotty at best. In 1982, concerned resource managers in the state of Florida organized the Exotic Pest Plant Council (EPPC). The EPPC was established to unify the exchange of information between land management agencies, research scientists, industry and other interested groups that were concerned with the impacts of exotic plants in natural areas, and to serve as an advisory body to other groups or agencies. The EPPC has identified a list of Florida's Most Invasive Species (Appendix 1). Brazilian pepper (*Schinus terebinthifolius* Raddi) is identified as a species that is widespread in Florida, and poses a significant threat to Florida's natural areas.

The Brazilian pepper Management Plan provides recommendations from the Brazilian Pepper Task Force (BPTF) - a working committee of the Exotic Pest Plant Council - for the integrated control of SBrazilian pepper in Florida. The BPTF is an interagency group of professionals who either have direct experience in managing Brazilian pepper or have the technical knowledge required for an integrated management approach. It is the consensus opinion of the BPTF that the uncontrolled expansion of Brazilian pepper constitutes one of the most serious ecological threats to the biological integrity of Florida's natural systems.
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PROBLEM STATEMENT

Brazilian pepper, native to Brazil, Argentina, and Paraguay (Mytinger, 1987), was initially introduced into the United States as an ornamental. This evergreen, dioecious, insect-pollinated tree belongs to the Anacardiaceae family (Loope and Dunevitz, 1981). It has bright red fruits and shiny green leaves which helped promote it as a popular holiday substitute for holly in Florida, quickly earning the misnomer Florida holly (Morton, 1969). Morton (1979) suggested that this plant was first introduced at the turn of the century by the Plant Introduction Service. However, Brazilian pepper was advertised in seed catalogs as early as 1832, over 60 years beforehand, in New York (Mack, 1991).

Brazilian pepper has been reported to have successfully naturalized in over 20 countries, now occurring in two sub-tropical belts (15-30*0* N and S) worldwide (Ewel et al., 1982). In the United States, Brazilian pepper (either *S. terebinthifolius* or *S. molle*) is found in Florida, Louisiana, Texas, California, Hawaii, as well as the commonwealth of Puerto Rico. Although Brazilian pepper is an aggressive colonizer in Florida and Hawaii, it has not become widely naturalized in southern California and is, in fact, still a popular ornamental.

Brazilian pepper is a pioneer of disturbed sites such as highway, canal and powerline rights-of-way, fallow fields, and drained cypress stands, but it is also successful in many undisturbed natural environments (Woodall, 1982). Brazilian pepper successfully colonizes many native plant communities, including pine flatwoods, tropical hardwood hammocks, and mangrove forest (Loope and Dunevitz 1981, Ewel, et al., 1982, Woodall 1982). The invasion of this aggressive, woody weed poses a serious threat to species diversity in many of Florida's native ecosystems, and is eliminating many indigenous sources of food for wildlife (Morton, 1979).

In addition to its threat to Florida's natural areas, Brazilian pepper also poses several health and safety problems. A relative of poison ivy (*Toxicodendron radicans*), direct contact with the sap can cause severe and persistent skin irritation. Airborne chemical emissions from the blooms can also cause sinus and nasal congestion, rhinitis, sneezing, headaches, and eye irritation in some individuals (Morton, 1979). Consumption of foliage by horses and cattle can cause hemorrhages, intestinal compaction, and fatal colic. Birds that feed excessively on the fruit have been known to become intoxicated and later die (Morton, 1978).

Several of its attributes have facilitated the spread of Brazilian pepper throughout Florida. Its fruits are commonly consumed by frugivorous birds. The dispersal of seeds by these birds, namely: mockingbirds, cedar-birds, and especially migrating robins has been responsible for the escape of this species into outlying, non-Brazilian pepper dominated ecosystems, especially those that include perches such as trees and utility lines (Ewel et al., 1982).

MAGNITUDE OF PROBLEM

Although specific introduction points are not clear, the popularization of Brazilian pepper in Florida can be attributed to plant enthusiast Dr. George Stone (Morton, 1978). In 1926, while residing in Punta Gorda on the west coast of Florida, he reportedly raised hundreds of these plants. These seedlings were then distributed among his friends and many were planted along city streets (Morton, 1978).

It wasn't until after 1950 that Brazilian pepper became conspicuously dominant in Florida (Ewel et al., 1982). Davis (1942) for example, did not remark on the presence of the species in his description of everglades vegetation. In 1969 however, biologists at Everglades National Park were expressing, with alarming concern, that Brazilian pepper had the potential to destroy many of South Florida's natural areas (Morton, 1979). Brazilian pepper now covers hundreds of thousands of acres in south and central Florida, as well as many of the islands on the east and west coasts of the State (Bennett and Habeck, 1991).
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GOAL

The goal of the Brazilian Pepper Task Force is to protect the integrity of Florida's natural ecosystems from the biological degradation caused by the invasion of Brazilian pepper.

OBJECTIVES The Goal of the Brazilian Pepper Task Force can be achieved through the following objectives:

1. Eliminate Brazilian pepper from Florida's natural ecosystems.

2. Achieve an overall reduction of Brazilian pepper throughout Florida such that maintaining Florida's natural areas Brazilian pepper-free is economically feasible.

3.Implement an effective public information awareness and participation program that will encourage support for Brazilian pepper management issues.
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RECOMMENDATIONS

The following are priority recommendations as suggested by the members of the BPTF.

1. Secure funding for the continued evaluation and subsequent release of Brazilian pepper biological control agents into Florida. The foundation of an effective control program for an aggressive pest-plant like Brazilian pepper requires the successful introduction of biological controls. Woody plant species such as Brazilian pepper require several different biocontrol agents to be effective.

2. Seek additional funding for the construction, staffing, and operation of a quarantine facility in South Florida. The total cost of building such a facility in South Florida has been estimated at **$4,000,000**. The U.S. Congress has authorized its construction and has allocated **$1,250,000** to date. While the facility is being promoted as a way to accelerate the search for biological control agents for melaleuca, the facility would also be available for other environmental weeds such as Brazilian pepper.

3. Encourage Brazilian pepper control programs for Florida's publicly-owned natural areas.

4. Enhance existing control programs through coordinated efforts to seek additional funding sources.

5. Seek partnerships with concerned citizen groups to participate in Brazilian pepper control programs. Citizen groups like the "Pepper Busters" of Brevard and Hillsborough counties are examples of successful volunteer programs. Concerned residents are trained in the latest techniques for controlling Brazilian pepper on public lands and urban areas.

6. Continue investigations into developing sound management options.

7. Use the support and resources of organizations such as the Exotic Pest Plant Council to organize a network of professionals to lobby the State Legislature and U.S. Congress to provide financial support and enact laws encouraging the management of Brazilian pepper and other exotic pest-plants.

8. Cooperate with agencies and organizations such as the water management districts, the Florida Department of Environmental Protection, the Cooperative Extension Service, and the Native Plant Society in the production and dissemination of information intended to educate the public about the problems associated with the introduction of

nuisance exotic plants such as Brazilian pepper.
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BIOLOGY OF BRAZILIAN PEPPER

Vernacular Names

Brazilian pepper (tree), Christmas berry (tree), Florida holly (USA); Copal (Cuba); Pimienta de Brasil (Puerto Rico); NANI-O-HILO (Hawaii); Aroeira (Brazil); Chichita (Argentina); Faux poivrier or False pepper (French Riviera).

Taxonomy & Classification

Brazilian pepper belongs to the Anacardiaceae, the Cashew or Sumac family, which comprises approximately 600 species in 70 genera (actual numbers of taxa vary among authors, with genera ranging from 60 to 80, and species from 600 to 850). Members of this family are found primarily in tropical and subtropical regions of the world, but are also represented in the floras of the Mediterranean, and temperate Eurasia and North America. Three genera are indigenous to southeastern United States: *Rhus* (including *Toxicodendron;* Sumac, Poison ivy), *Metopium* (Poison wood), and *Cotinus* (Smoke tree) (Brizicky 1962). A number of additional genera have been introduced and are cultivated for their edible fruits or seeds (*Mangifera*, Mango; *Pistacia*, Pistachio; *Spondias*, Hog plum), or ornamental qualities (*Schinus*, Pepper tree). In Florida, the family is represented by one to several species in each of the aforesaid genera, except *Cotinus*.

Members of the Anacardiaceae are readily characterized by the presence of resin (or sometimes latex) ducts, pinnately compound or trifoliolate leaves, typically 5-merous flowers with a nectary disc, and drupaceous fruits. The resin is often toxic and allergenic. In addition to their economic value as fruit and nut trees, and ornamentals, the family is recognized as a source of dyes, tannins, resins, oils and lacquers, waxes and varnishes, and commercial timber (Brizicky 1962; Tomlinson 1980). It is classified under the large plant order Sapindales, together with the Rutaceae (Citrus family), Meliaceae (Mahogany family), Aceraceae (Maple family), Sapindaceae (Soapberry family), and others.

Brazilian pepper joins approximately 29 other species in the genus *Schinus* L., a name given by the famous Swedish naturalist, Carolus Linnaeus, when he first established the genus in 1753. The name *Schinus* is derived from the word 'schinus', the Latin name for the Mastic tree (*Pistacia lentiscus* L.), also of the same family, which this genus resembles in its resinous juice (Correll & Correll 1982). In a taxonomic revision of the genus, Barkley (1944) divided *Schinus* into two groups (subgenera) based on leaf and inflorescence characteristics. Brazilian pepper (together with about five other species, including *S. molle* L., California pepper) belongs to Subgenus *Euschinus* which is characterized by unarmed shrubs and trees having mostly pinnately compound leaves and large paniculate inflorescences. The remaining species are placed in Subgenus *Duvaua*, all of which possess simple leaves and mostly pseudoracemose inflorescences; the majority have armed branches.

Brazilian pepper, *Schinus terebinthifolius* Raddi, was first described in 1820 by the Italian, Giuseppe Raddi (1770-1829). The name *terebinthifolius* is derived from the Latin words 'terebinthus', the Latin name for the Terebinth tree (*Pistacia terebinthus* L.), and 'folium', leaf, in reference to the resinous leaves of this species, like those of Terebinth. Barkley (1944) recognized five varieties of *S. terebinthifolius*, three of which were known to occur (as introductions) in the United States prior to his publication and cited by him, namely var. *terebinthifolius* (reported from Florida and California), var. *acutifolius* Engl. (Michigan, Missouri, and California), and var. *raddianus* Engl. (Florida). The remaining two varieties, var. *pohlianus* Engl. and var. *rhoifolius* (Mart.) Engl., were not reported to occur here. Campbell *et. al.* (1980) comments on the possibility of hybridization occurring among the varieties established in Florida. (See following section on "Vegetative & Reproductive Morphology" for characterization of varieties)

Schinus terebinthifolius has been referred to by other names (synonyms) in the past, including *S. mucronulata* Mart. (in reference to the pointed leaf tip or mucro) and *S. antiarthriticus* Mart. (in reference to the supposed anti-arthritic action of its resin).

Vegetative & Reproductive Morphology

Habit Brazilian pepper is an evergreen shrub or small tree, 3-7 meters tall or more. Its trunk is often multiple-stemmed. Multiple-stemmed trees originate in one of two ways: from sprouting due to damaged trunks and crowns, and from germination of several fruits at the same point, *e.g.*, from seeds dispersed in animal scat. When growing in open areas, the crowns of these trees are broad and rounded and comprise numerous, long, arching, leafy branches which often reach the ground. Ewel *et. al.* (1982) noted that these branches do not easily self-prune and "remain attached to the tree, forming an impenetrable tangle that surrounds the tree to ground level". The crowns of trees growing in dense, closed stands, on the other hand, differ in having the foliage concentrated at the top of the canopy, leaving the lower (understory) branches relatively leafless.

Vegetative Morphology The odd-pinnate (compound) leaves are alternately arranged on branches and range from 8 to 17 cm in length (Fig. 1a). Each leaf is composed of usually 4 or 6 (or sometimes more) lateral leaflets, arranged in pairs along a narrowly winged leaf axis (rachis), and a single, terminal leaflet. The short petiole (to 3 cm long) is unwinged, and each leaflet is attached to the rachis by a very small stalk (subsessile). The leaf petioles and racheae (as well as the expanding leaf blades and shoot apices) are often tinged red. The leaflets are oblong-elliptic to obovate in shape, to 10 cm long by 4.5 cm wide, with blunt or rounded to pointed tips, tapering, sometimes asymmetric, bases, and toothed to subentire margins (Fig. 2a). The leaflet blades are thinly leathery, and glossy, dark green above and dull, pale green below. Each blade is conspicuously veined above (less conspicuous below), with 10-12 lateral nerves on each side of the midrib. When crushed, the leaves produce a pungent aroma that has beenvariously described, from "peppery" to "turpentine-like". In the axils of the leaves are found one or two buds. If occurring singly, the bud will remain dormant. If occurring in pairs, *i.e.*, serial buds (Fig. 1d), the uppermost bud has the potential to develop into a flowering shoot (Tomlinson 1980). The description above applies to typical Brazilian pepper, var. *terebinthifolius.* There are a number of vegetative differences between it and the other four recognized varieties, mainly in leaf length, number of leaflets, and leaflet shape and margins. These differences are noted below (after Barkley 1944; Campbell *et. al*., 1980):

% var. *acutifolius* - leaves 7-22 cm long; leaflets 7-15, lanceolate in shape, margins obscurely toothed to smooth (entire), tips pointed, sessile; petiole to 4 cm long.

% var. *pohlianus* - leaves 7-19 cm long; leaflets 5-17, oval to obovate in shape; petiole to 4 cm long; rachis broadly winged; stems and leaves velvety-hairy.

% var. *raddianus* - leaves 7-16 cm long; leaflets 3-9, obovate in shape, terminal leaflet larger than laterals, margins toothed to nearly entire, tips rounded.

% var. *rhoifolius* - leaves 5-17 cm long; leaflets 3-7, oval to obovate in shape, terminal leaflet larger than laterals, margins mostly entire, tips rounded.

Campbell *et. al.* (1980) noted that Brazilian pepper is extremely variable in Brazil (and to a lesser degree in Florida), and that many exceptions to the general morphological descriptions can be expected. Due to difficulty in separating the varieties, *e.g.*, morphological characters often overlap in the field, southern Florida populations have not been adequately characterized or classified to the varietal level.

Reproductive Morphology Brazilian pepper is largely a dioecious plant which means that the flowers are all unisexual, *i.e.*, either male (staminate) or female (pistillate), and the sexes are physically separated, *i.e.*, occur on male and female trees. Ewel *et. al.* (1982), however, observed that a small number of trees in a population produce bisexual ("complete") flowers or are monoecious, *i.e.*, unisexualflowers occur on the same individual. The flowers are produced in showy, branched inflorescences (panicles), 2-11 cm long, which arise from the axils of leaves near the ends of stems (Fig. 1b). In addition to flowers, the inflorescences also bear triangular to lanceolate, leaf-like bracts with ciliate margins. Both male and female flowers (Fig. 2b-j) occur on stalks (pedicels) 1 mm long and essentially have the same structure: 5 small, green, triangular sepals with ciliate margins; 5 small, white, glabrous, ovate petals; 10 stamens concentrically arranged in 2 series of 5, the outer series being longer; a lobed disc at the base of the stamens; and a single-chambered (unilocular) ovary with 3 short styles. However, in male flowers, the ovary (pistillode) is non-functional, and in female flowers, the stamens (staminodes) are sterile. On female trees, flowering is followed by the production of bright red, fleshy, spherical drupes ("berries"), each 5-6 mm in diameter and containing a single seed (Fig. 1c).

The description above applies to typical Brazilian pepper, var. *terebinthifolius*. There are a number of morphological differences between it and the other four recognized varieties, mainly in inflorescence and pedicel lengths, sepal, petal and fruit characters, and hairiness (pubescence). These differences are noted below (after Barkley 1944):

% var. *acutifolius* - inflorescences 3-15 cm long, sparsely hairy, bracts ciliate; pedicels 1.5-2 mm long; sepals triangular-ovate, margins ciliate; petals lanceolate, mostly glabrous; fruits pink, 5 mm in diameter.

% var. *pohlianus* - inflorescences 2-8 cm long, soft-hairy, bracts triangular; sepals triangular- ovate; petals lanceolate.

% var. *raddianus* - inflorescence bracts triangular, sparsely glandular; sepals triangular- ovate; petals lanceolate.

% var. *rhoifolius* - inflorescences 1-9 cm long, bracts triangular; pedicels 1 mm long; sepals triangular-ovate; petals lanceolate to narrowly ovate.

Reproductive Biology, Phenology, and Growth

Although occurring sporadically throughout the year, flowering and fruiting phenomena in Brazilian pepper shows distinct periodicity. The main flowering period, September to October, is marked by the production of copious flowers from axillary inflorescences developing at the ends of leafy branches. A second flowering period (March-May) occurs in less than 10% of the population (Ewel *et.al.* 1982). Observations by Ewel *et.al.* (1982) reveal that Brazilian pepper is pollinated by diurnal insects, including a number of dipterans (especially a syrphid fly, *Palpada vinetorum*), hymenopterans, and lepidopterans. Male and female flowers supply nectar (secreted by the floral disc) and/or pollen to the foraging insects. Pollen availability and nectar secretion in Brazilian pepper flowers is apparently timed to maximize pollination success, although Ewel *et. al.* (1982) suggested this is unnecessary in southern Florida due to the diversity of local insect pollinators (many of which are considered to be nectar and pollen "thieves") and good fruit set. Plants appear to be out-crossers, although the rare occurrence of fruits (under experimental conditions) developing from unisexual flowers has not been adequately explained.

Fruit production occurs during the winter (November to February), at which time the branches of female trees are heavily laden with red fruits while male trees remain barren. Ewel *et. al.* (1982) observed that ripe fruits are retained on a tree for up to 8 months, and all will be dispersed before the next flowering season. The attractive fruits are readily eaten and transported by birds and mammals, with water and gravity serving as less important dispersal agents. Seed dispersal by native and exotic birds, *e.g.*, catbird, mockingbird, American robin, red-whiskered bulbul, accounts for the presence of Brazilian pepper in almost every terrestrial plant habitat in southern Florida (Austin 1978; Ewel *et. al.* 1982; Ewel 1986). Robins, when they are present, are believed to consume and transport more *Schinus* seed than all other dispersal agents combined. Raccoons and possibly possums are known to ingest the fruits, theirstool providing additional nutrients for seed germination and seedling growth (Ewel *et. al.* 1982). The fact that very little else is fruiting during the winter months when *Schinus* seeds are dispersed has been suggested as a possible explanation for the success of Brazilian pepper in southern Florida (Ewel 1986).

Greenhouse experiments carried out by Ewel *et. al*. (1982) on Brazilian pepper indicate a germination rate of 20-60% (compared to 1-30% in the field), with most germination occurring within the first 20 days. The germination period ranges from November to April (and sometimes to as late as July!), with the highest activity occurring during January-February. Seeds are generally not viable after 5 months following dispersal. However, Ewel (1979) reported seed germination in late fall, under certain conditions; seeds apparently retain their viability during the wet season floods and germinate when water levels drop late in the year.

Water availability, especially rapid changes in water levels, determines to a great extent seedling success: seedlings are especially susceptible at the end of the dry season (May-June), which corresponds to the period of greatest germination activity, and during the wet season (July-September), where prolonged submergence may result in increased seedling mortality (Ewel *et. al.* 1982). Its lack of success in southern California has, in fact, been attributed to the short period of sufficient soil moisture needed for germination and root establishment (Nilsen and Muller 1980). Other density-dependent and density-independent factors may also influence patterns of success and mortality in Brazilian pepper seedlings in southern Florida.

Ewel *et. al.* (1982) discussed seedling survivorship in some detail and concluded that the tenacity and growth plasticity of Brazilian pepper seedlings is unusual and makes this species especially difficult to manage. Seedlings grow very slowly and can survive under the dense shade of mature stands, while exhibiting vigorous growth when the canopy is opened after a disturbance. In exposed, open areas, suchas young successional communities, their rates of growth are among the highest, *i.e.*, 0.3-0.5 m per year.

Vegetative growth in Brazilian pepper undergoes a cycle of dormancy in winter (October-December), when flowering occurs, followed by shoot renewal and extension growth (evidenced by the production of long, drooping branches) more or less continuously throughout the rest of the year (Tomlinson 1980; Ewel *et. al.* 1982). While there is no general relationship between vegetative growth and reproductive development, *i.e.*, inflorescence initiation and growth, branches can terminate all subsequent vegetative growth (in other words, become determinate) if flowering is prolific (Tomlinson 1980).

Like many hardwood species, Brazilian pepper has the capability of resprouting from above-ground stems and root crowns, under certain conditions, *e.g.*, cutting to a stump, bark girdling, fire (if it girdles a stem), herbicide application (Woodall 1979). Resprouting is often profuse and the growth rates of the sprouts, which originate from dormant and adventitious buds, are very high. Brazilian pepper's generally shallow root system (because of high water tables) also favors the production of underground root suckers. Root suckers form without evidence of damage to a tree or its root system and can develop into another individual. The clumping of *Schinus* often seen during the early stages of invasion can be explained by this suckering mechanism (Woodall 1979).

Ewel (1979) summarized the many characteristics of Brazilian pepper which make it the successful weedy species that it is, including : (1) fast growth, (2) prolific seed production, (3) near continuous shoot extension and leaf renewal, (4) vigorous resprouting, and (5) tolerance of a wide range of growing conditions (see next section). It is unique among weed species, however, in possessing a number of traits more typical of mature ecosystem species, including: (1) synchronous flowering and fruiting within a short time period, (2) male and female flowers produced on separate individuals, *i.e.*, dioecious, (3) pollination by insects, (4) large, animal-dispersed seeds, (5) large cotyledons (important for seedling success), and (6) shade tolerant seedlings.

Chemistry and Toxicity

Phytochemical studies carried out during the 1960-70's revealed the presence of a number of diverse chemical compounds, including triterpene alcohols, ketones, acids, monoterpenes, and sesquiterpenes, in the bark, leaves and fruits of Brazilian pepper (Lloyd *et. al.* 1977; Morton 1978). The high concentration of volatile (and aromatic) monoterpenes, *e.g.*, %-pinene, limonene, %3 -carene, has been suggested to be a probable cause of the respiratory problems associated with crushed fruits. The fact that widespread respiratory ailments have occurred when the tree is in bloom suggests that these same volatile compounds may also be produced by the flowers (Lloyd *et. al.* 1977). Morton (1969, 1978) reports that persons sitting or playing beneath Brazilian pepper trees exhibited flu-like symptoms, and sneezing, sinus congestion, chest pains and acute headache were among the possible inhalant effects. It is of interest to note that the pollen from its flowers appears not to be a significant source of irritation or allergies, as it is sticky and not easily carried by wind (Morton 1978).

Campello & Marsaioli (1974) noted in a paper on triterpenes that the ingested fruits have a "paralyzing effect" on birds. The narcotic and toxic effects on birds and other wildlife has also been noted by others, *e.g.*, Bureau of Aquatic Plant Management. Workman (1979) refers to the "hypnotic action" of fruit extracts, containing the triterpenes terebinthone and schinol, on chicks and mice. The *AMA Handbook of Poisonous and Injurious Plants* (Lampe & McCann 1985) reports that the tripterpenes found in the fruits can result in irritation of the throat, gastroenteritis, diarrhea, and vomiting in man.

Like most other members of the Anacardiaceae, Brazilian pepper contains active alkenyl phenols, *e.g.*, urushiol, cardol, which can cause contact dermatitis and inflammation in sensitive individuals (Lampe & Fagerstrom 1968; Tomlinson 1980). Contact with the "sap" from a cut or bruised tree can result in rash, lesions, oozing sores, severe itching, reddening and swelling (especially of the eyes), and welts (Morton 1978). Grazing animals, such as horses and cattle, are also susceptible to its toxic effects, and ingestion of leaves and/or fruits has been known to be fatal.

Of taxonomic interest is the observation that the chemistry of Brazilian pepper, specifically certain compounds extracted from the leaves and bark, is more similar to species of the related genus *Pistacia* than it is to other members of its own genus *Schinus* (Campello & Marsaioli 1975).

Distribution and Ecology

The genus *Schinus* occurs naturally in South America, with one species (*S. molle* L.) ranging as far north as Mexico. Brazilian pepper is indigenous to subtropical Brazil, Paraguay, and Argentina, and has been introduced to various subtropical regions of the world including other parts of South America, Central America, the Bahama Islands, the Caribbean Islands, the United States, Mediterranean Europe, northern and South Africa, China, southern and southeastern Asia, Australia, and the Pacific Islands (Morton 1978; Campbell *et. al.* 1980).

In its natural range, it is reported to occur as scattered individuals in a variety of habitats, from sea level to over 700 m elevation (Ewel *et. al.* 1982). It never dominates the landscape as it does insouthern Florida (Campbell *et. al.* 1980; Ewel 1986), where it grows on a broad range of moist to mesic sites, sometimes forming nearly monotypic stands, including tropical hardwood hammocks, bay heads, pine rocklands, sawgrass marshes, *Muhlenbergia* prairies, and the salt marsh-mangrove transition zone. In this region, it thrives on disturbed soils created by natural disruptions, *e.g.*, hurricanes, and is especially invasive in areas affected by human activities, particularly the newly created habitats resulting from agriculture and drainage, *e.g.* abandoned farmlands, roadsides, canal banks (Ewel 1986).

Brazilian pepper does not become established in deeper wetland communities and rarely grows on sites inundated longer than three to six months. In Everglades National Park, for example, it is absent from marshes and prairies with hydroperiods exceeding six months as well as from tree islands with closed canopies (LaRosa *et. al.* 1992).

Preliminary investigations on *Schinus* invasibility (employing seed introduction and seedling transplant experiments) in both native (undisturbed) and successional (disturbed) plant communities in southern Florida were carried out by Ewel *et. al.* (1982). Young successional communities were found to be more susceptible to invasion than older ones, and all successional communities were more susceptible than undisturbed, native communities. Of the three native "ecosystems" investigated, the pinelands were more susceptible to *Schinus* seed germination, followed by wet prairies ("glades") and hammocks. Successful invasion appears to be a function of both seed access to an area and the ability of introduced seeds to germinate and seedlings to survive (Ewel *et. al.* 1982).

Concern over the occurrence of *Schinus* in salt-tolerant plant communities, *e.g.*, mangrove forest, in southern Florida, especially in Everglades National Park, led Mytinger and Williamson (1987) to investigate the tolerance of *Schinus* to saline conditions. Seed germination and transplanted seedlings did not succeed at salinities of 5 ppt or greater, which would largely exclude it from becoming establishedin mangrove forest. *Schinus* invasion of saline communities can occur, however, if salinity declines due to changes in drainage patterns resulting from natural phenomena or human activities.

The ability of Brazilian pepper to invade disturbed, successional habitats in particular, *e.g.* abandoned agricultural fields formerly rock-plowed, is due to the enhanced conditions created by an altered substrate, *i.e.*, the soil is deeper, better drained, better aerated, and possibly more nutrient-rich (Ewel *et.al.* 1982). This promotes the growth of mycorrhizal fungi in association with *Schinus*, allowing them to colonize areas that they would otherwise be unable to grow in.

The stages of secondary plant succession in abandoned, rock-plowed farmlands, leading to nearly pure stands of Brazilian pepper, have been well-documented in studies carried out in the Hole-in-the-Donut area of Everglades National Park utilizing *Schinus* tree and stem inventories, seedling density data, and forest understory characteristics (Loope and Dunevitz 1981a; Ewel *et. al.* 1982; Krauss 1987). The general course for secondary succession (and *Schinus* invasion) on these rock-plowed farmlands is summarized in Doren and Whiteaker (1990): the process progresses (on sites < 10 years old) from low density and reproduction in *Schinus* in a matrix of grasses and herbs, through (on sites 10-20 years old) a stage of rapid reproduction and increased density, to (on sites > 20 years old) dense stands of nearly pure *Schinus* that are "self-maintaining". The conclusion is that monotypic Brazilian pepper forests represent the final stage in secondary plant succession on abandoned farmlands. The use of repeated fires as a management tool for controlling successional growth *Schinus* in these areas has been investigated by Doren *et. al.* 1991. Although repeated burnings may slow down the invasion rate, it does not exclude its establishment; *Schinus* invasion progresses with or without the occurrence of fire.

Brazilian pepper forest structure in the Hole-in-the-Donut region of Everglades National Park was documented by Ewel *et. al.* (1982) and revealed stands containing from 200 to more than 2500 *Schinus*trees per hectare. The understory of even the densest stands contains ferns and shrubs, such as the exotic *Ardisia elliptica*. A number of native and exotic trees (*Myrsine floridana*, *Persea borbonia*, *Ilex cassine*, *Nectandra coriacea*, *Psidium guajava*) are also known to successfully invade, and establish small populations of individuals within, *Schinus* stands. Gogue *et. al.* (1974) have suggested that Brazilian pepper has the ability to inhibit the growth of competing vegetation through the production of allelopathic substances.

Brazilian pepper stands provide relatively poor wildlife habitat. In a study on the utilization of a mature Brazilian pepper stand by the native avifauna, Curnutt (1989) found that avian species diversity and total population density declined when compared to native pinelands and forest-edge habitats. Such results, expected when a species-rich habitat is replaced by one which is biologically less diverse, stress the need to protect native habitats from exotic pest plant encroachment.

Of interest is the experimental evidence that the native *Myrica cerifera* (Wax myrtle) is allelopathic and inhibitory to Brazilian pepper germination and seedling establishment (Dunevitz and Ewel 1981). In previously farmed pinelands where Wax myrtle has become dominant, Brazilian pepper has been observed to have slower growth rates and poorly developed seedlings. Their reduced vigor under these conditions suggests a possible use of Wax myrtle in Brazilian pepper management practices (Dunevitz and Ewel 1981).

Brazilian pepper is not a fire adapted species. Studies conducted in southern California by Nilsen and Muller (1980) indicated that Brazilian pepper seeds are killed by fire; seeds must be introduced to a site after a fire in order to establish seedlings.

Fire management practices have determined the extent of invasion of limestone rockland pine forests by *Schinus* in southern Florida. Because Brazilian pepper seedlings require several years after germination in these forests to reach a size capable of surviving fire, *i.e.*, about 1 m tall for 80-90% survivorship (% survivorship decreases as seedling height decreases), fires can effectively eliminate and exclude *Schinus* establishment in pinelands which are regularly burned at about 5 year intervals (Loope and Dunevitz 1981b). Larger trees are normally killed down to ground level after a fire but vigorously resprout from the bases of single stems. This, in combination with their rapid vegetative growth and ability to out-compete native hardwood species, increases *Schinus* dominance of the stand. Brazilian pepper has largely been excluded from rockland pine forests where adequate fire management programs are carried out, *e.g.*, Everglades National Park. Quite the opposite is true for the few remnant pine stands elsewhere in Dade County where lack of such programs has accelerated *Schinus* establishment with the concomitant loss of biological diversity.

Economic Uses

Before Brazilian pepper attained its present status [in southern Florida] as a serious pest plant, it was widely planted along city streets and in home gardens because of its ornamental qualities and for shade (Morton 1969). Its decorative fruiting branches were particularly valued at Christmas, and the clusters of fruits were used to make leis and adorn hats (Morton 1978). It has been successfully grown indoors: Graf (1982) provides information on its cultivation requirements ("a large container and plentiful watering") and propagation ("from cuttings and seeds").

As its vernacular name suggests, the dried fruits of Brazilian pepper are used as a spice and sold in the United States as "pink peppercorn". With regard to this, Bell & Taylor (1982) noted that "due to its toxic properties, its use in this way is inappropriate and potentially dangerous". In areas of South America where it occurs naturally, the plant is considered tonic and astringent, and the stems are thesource of a resin called Balsamo de Misiones (Uphof 1968). In Brazil, the plant is considered medicinal (Campbell *et al.* 1980; Morton 1978) and used in remedies for ulcers, respiratory problems, wounds, rheumatism, gout, tumors, diarrhea, skin ailments, and arthritis. Brazilians also value the bark for tanning where it is sold in fishing equipment shops and used to preserve fishing lines and nets (Mors & Rizzini 1966; Morton 1978). Campbell *et. al*. (1980) reports that Brazilian children play with the leaves by igniting them and watching them "pop and sparkle". Morton (1978) described several products made from Brazilian pepper: toothpicks from its twigs, posts, stakes and construction materials from its wood, and honey from its copious nectar. It is recognized as an important nectar and pollen source by the bee industry in Hawai'i (Yoshioka and Markin 1991).

A number of economic uses are reported for other members of the genus as well. The fruits of California pepper, or Peruvian mastic, *Schinus molle* L., said to contain an essential oil, are pulverized and used to make refreshing drinks known as 'horchatas' or 'atoles', while gum from the trunk is reportedly used in varnishes and medicines, and for chewing (Uphof 1968; Williams 1981). Altschul (1973) reports that this species is used in the treatment of rheumatism in Mexico. In Peru, it is employed in the preparation of a mildly alcoholic drink (Rehm & Espig 1991). Like Brazilian pepper, its dried fruits, exported from Peru and Ecuador to the United States, are used like pepper (or even to adulterate it!), and the essential oils from its leaves and fruits are used as an aromatic (Rehm & Epsig 1991). The bark is used for tanning animal skins (Graf 1982), and when powdered, it serves as a purgative for domestic animals (Uphof 1968). A wine is reportedly made from small twigs (Hedrick 1972). Mabberley (1987) notes its use as a fertility control agent in Uruguay.

Another species, *S. polygamus* (Cav.) Cabrera (= *S. dependens* Orteg.), is used in Chile to treat rheumatism, and a red wine is prepared from its 'berries'. The fruits of *S. latifolius* (Gillies) Engl. are used by Chilean indians to make an intoxicating liquor (Uphof 1968; Hedrick 1972).

Ecological Impact

An evergreen shrub, Brazilian pepper has invaded many habitats in central and southern Florida. It tends to prefer better-drained soils (Ewel, 1986) or short hydroperiod wetlands that are organic (Duever et al., 1986). Local dispersal of its seeds is primarily by raccoons and opossums; long distance spread is facilitated by frugivorous birds such as migratory American robins (Thurdus migratorius) (Ewel et al., 1982; Anonymous, 1988). Although primarily an invader of landscapes in which substrate is disturbed and fire excluded (Loope and Dunevitz, 1981), it has formed large, dense forests in relatively undisturbed areas adjacent to mangroves along the southwestern portion of Everglades National Park. Ewel (1986) concluded that because of the important differences in melaleuca (Melaleuca quinquenervia) and Brazilian pepper in respect to their relationship to fire and water regimes, they tend to invade different habitats, and "they seem to have divided their spoils fairly equitably in Florida.

Although Brazilian pepper has been studied more than most other nonindigenous plant species in Florida, comprehensive investigations of its ecosystem effects ar lacking. It is known, however, to form dense monospecific stands in southern Florida that almost completely displace native understory plants (Ewel, 1986). Because its leaves decompose rapidly, little leaf litter accumulates beneath these stands (Ewel, 1986). Although 46 phytophagous insect species have been collected from Brazilian pepper in Florida (cassani, 1986), they do not appear to retard plant growth or vigor (Cassani, 1986; Cassani et al., 1989; Bennett and Habeck, 1991). A single season breeding-bird survey in an Everglades Brazilian pepper forest (Curnutt, 1989) showed total density to be only 73 pairs/100 ha and species richness to just six species, whereas Robertson (1955) found 28 species and more than 113 pairs/100 ha in pineland located in the Everglades and 18 species and more than 255 pairs/100ha in the forest edge. However, the lower recent bird density and richness in Brazilian pepper forests may also reflect an overall decrease in breeding birds found in upland forests of Everglades National Park since 1955 and may be related to factors other thanhabitat disruption (Snyder et al., 1990). On the other hand, anecdotal information suggests that mangrove bird rookeries surrounded by Brazilian pepper have been abandoned (Beever, 1994).

A few native amphibian and reptile species were collected (though rarely) in Brazilian pepper forest habitats in the Long Key-Paradise Key region of the Everglades National Park, whereas two nonindigenous species, Cuban tree frogs (Osteopilus septentrionallis) and brown anole lizards (Anolis sagrei), were most common (Dalrymple, 1988). Dalrymple (1988) believes that most of the herptofauna in Brazilian pepper forests in this area was responding to basic microhabitat requirements and not the species composition of the vegetation. The herptofauna of Brazilian pepper forests is similar in species numbers and foraging guilds to those of southern Florida's hammock communities, probably because of the closed canopy conditions. and soil development found in both (G. Dalrymple, pers. comm). In Everglades National Park, anecdotal evidence suggests Brazilian pepper spread is threatening the nesting habitat of the gopher tortoise (Gopherus polyphemus), a species threatened in Florida.

Two types of plant invaders are particularly likely to have major impacts on ecosystems: those that constitute novel habitats and species that modify existing habitats often by altering ecological processes (Vitousek, 1986; Simberloff, 1991). Brazilian pepper can do both in Florida. Undisturbed moist pine flatwoods have been extensively invaded in some areas by Brazilian pepper in South Florida (Abrahamson and Hartnett, 1990). These invasions in pine flatwoods have led to closed canopies conditions, or a dense, shrub forest, in a previously open understory shrub layer constituting a novel habitat. Brazilian pepper invasions in mesic prairies also constitute novel habitats in Florida. Brazilian pepper appears to have the competitive advantage over native flora in that seedling survivorship is usually high (66 - 100%) (Ewel et al., 1982). Fire is important to almost every terrestrial ecosystem in South Florida. Because leaf litter from Brazilian pepper's forest canopy decomposes quickly in Florida, this may lead to changes in disturbance frequency caused by wildfires (more resistant to seasonal burns). For example, fires will burnthrough pinelands and short hydroperiod prairies in Everglades National Park, however, fire is usually halted where Brazilian pepper monospecific stands begin (D. Jones, pers. comm.). When Brazilian pepper does burn, the above ground parts of the plant are killed, but the tree promptly resprouts from the base (Ewel, 1986).

Economic Impact

Honey bees can use Brazilian pepper flowers. Sanford (1987) lists Brazilian pepper as one of Florida's best nectar-producing plants and commented that "the honey has a distinct peppery taste and is not considered by many to be of table grade, but is accepted well locally." It was estimated in 1989 that beekeepers sold from 6 to 8 million pounds of honey from Brazilian pepper per year in Florida (Schmitz, 1989). In addition, Brazilian pepper is considered to be important in bee maintenance during the winter months (Schmitz, 1989). However, the African honey bee (Apis mellifera scutellata), expected to arrive in Florida during the 1990s, may have a much greater impact on the state's bee industry (Office of Technology Assessment, 1993) than Brazilian pepper control efforts.

Because Brazilian pepper grows low to the ground and contains many crooked branches, it precludes economical harvesting by any conventional means for wood utilization (Morton, 1978). Morton (1978) also reports the strength characteristics would rank Brazilian pepper with the poorest of native hardwoods, and the extractive could pose a serious processing problem. The possibility of using Brazilian pepper for pulpwood has been tentatively explored. Morton (1978) found the species cannot be debarked using conventional equipment. However, the pulp yield is comparable to that from other hardwood pulps. It has been suggested it could be used for many paper grades such as printing, tissue paper and corrugating board.

In Brazil, the crushed, dried leaves of Brazilian pepper are applied as an antiseptic on skin ulcers; are eaten to relieve bronchitis and other respitory ailments; and are considered to be a remedy for gout, muscular agony, pain of arthritis, diarrhea, intestinal weakness, and inertia of human reproductive organs (Morton, 1978). In Florida, it is doubtful that many people use Brazilian pepper for medicinal purposes. Anecdotal evidence suggests Brazilian pepper can cause human contact dermatitis, allergies, and respitory problems (Office of Technology Asssessment, 1993).

Although once extensively sold as a landscape ornamental (one Central Florida nursery, Royal Palm Nurseries, Onceco, in 1937 advertised it as "one of our most worthwhile plants for general landscape purposes, as it makes a fine subject for mass planting and succeeds well along the beach, standing quite a lot of salt spray") from the 1920s through the 1960s, it was banned for commercial use in 1990. The banning of Brazilian pepper in 1990 as a landscape ornamental had no economic impact on the wholesale and retail industry (Schmitz, 1989) because the plant was no longer considered to have ornamental value by then

By infesting at least 700,000 acres of South Florida's landscape (Schmitz, 1994), Brazilian pepper may ultimately negatively impact Florida's tourist industry. Many visitors come to Florida to enjoy Florida's unique landscape and pay millions of dollars each year to gain admission to Everglades National Park and other preserved natural habitats (Schmitz, 1989). Any minimization of the spread of Brazilian peppers in these areas would maintain the interests of such visitors and the extent of their expenditures, including park or preserve admission, purchases of food, gasoline, and supplies and all the related permit fees and taxes. For example, tourist development taxes in Broward, Dade, Lee, Monroe, and Palm Beach counties were worth nearly $23 million in 1987 (Schmitz, 1989).

Biological Control Research

Classical biological control involves moving host-specific natural enemies from the native range of the weed to its introduced range. The goal is to reduce weed abundance to a level that can be tolerated. Biological control does not eradicate weeds. It simply restores a natural balance between the weed and its enemies. Biological control can be self-regulating since the introduced natural enemies often become part of the ecosystem.

Biological control is not a quick fix. The period of time between initiation of a weed biocontrol program and when the first natural enemy is released is measured in years. Release must be approved by both state and federal agencies. Releases require propagation of large numbers and distribution in the field followed by monitoring to determine whether establishment has occured and how effective the natural enemies are.

In Florida there are many insects associated with Brazilian pepper (Cassani 1986, Cassani, et al. 1989), but only one, the phytophagous seed wasp (*Megastigmus transvaalensis*) was abundant enough to cause significant seed reduction (Habeck et al 1989). Infestation rates of seeds are usually less than 5 percent, but can be as high as 30 percent in some localities.

In 1986, the Department of Entomology and Nematology of the Institute of Food and Agricultural Sciences (IFAS) initiated a biological control agreement with the University of Sao Paulo in Brazil. This included short duration surveys in southern Brazil to determine the range of Brazilian pepper's natural enemies and to determine the insect fauna on the plant in Florida. To date, more than 200 insect species have been found associated with Brazilian pepper in Brazil (Bennett and Habeck 1991 and Bennett et al 1990). Several of these insects were selected as potential biological control candidates for further study. Permission was obtained to bring some of them into quarantine in Florida for host specificity and biological studies.

The two insects that have recieved the most attention are the Brazilian peppertree sawfly (*Heteroperryia hubrichi*) Hustache (Pergidae: Hymenoptera); a defoliator, and Brazilian peppertree thrips (*Liothrips ichini)* Hood (Phlaeothripidae: Thysanoptera). The thrips was studied by Garcia (1977) who considered it likely to be host-specific to Brazilian pepper since he never found it on any other plant species. This insect is usually found as adults on newly unfolding and as nymphs on young stems. They damage the plant with their rasping-sucking mouthparts and frequently kill the new shoot. They also attack flowers causing them to abort. This restricts the vigor and growth rate of young plants and if established in Florida could remove the competitive advantage that Brazilian pepper currently holds over the native Florida vegetation.

In Brazil the larvae of the thrips are parasitized by a small wasp that limits its impact on Brazilian pepper. This wasp would be eliminated during the standard quarantine procedures required to clear biological control agents for field release. In the absence of this wasp, the thrips should have a more devastating impact on the growth rate of Brazilian pepper. The brazilian peppertree sawfly is a primative wasp that does not sting. Caterpillar-like larvae feed in groups, defoliating the plant. The immature stages (Larvae) are almost an inch long when mature. While this insect is also believed to be host-specific, it is proving difficult to rear in quarantine.

Other insects of interest found during preliminary studies include a bruchid beetle (*Lithraeus atronotatus*) whose larvae feed in and destroy fruit, a stem-tip gall maker (*Crasimorpha infuscata*), a flower feeding casebearer (*Coleophora sp.*) and unidentified flower-infesting gall midge, several leaf tiers and several weevils. The seed braced, one leaf tier and the stem tip gall maker were introduced into Hawaii to control Brazilian pepper but only the first two became established in the field. The leaf tier has had no appreciable impact on Brazilian pepper whereas the infestation rate of seeds by the braced increased to about 10 percent. It later dropped to a negligible level following the appearance of the phytophagous wasp (*M. transvaalensis*) that now infests 10 - 15 percent of the seeds (Yoshioka and Markin 1991).

The goal of this biological control program is to select and introduce natural enemies that will restrict seed production and reduce the vigor and growth rate of seedlings and young plants. To date, the field surveys have covered only a small portion of the distribution of Brazilian pepper in South America and there are indications that the biotype of Brazilian pepper that we have secured most of our thrips and sawfly on may not match the biotype occurring in Florida. Exploration of other areas, perhaps in the company of a qualified botanist should be implemented.

Mechanical Control

Mechanical control of Brazilian pepper is accomplished through the use of heavy equipment such as buldozers, front end loaders, root rakes and other specialized equipment. The use of heavy equipment is sometimes not suitable in in natural areas. Once undisturbed soils have been unsettled, they are succeptable to invasion by invasive exotic pest-plants. Mechanical control is accepted along ditch banks, utility rights-of-way and other disturbed areas. As followup, a herbicide application is highly recommended to prevent regrowth from the remaining stumps. Stumps that fail to be chemically treated will resprout and continue to infest natural areas and wetlands.

A chainsaw may be used for the removal of single trees or small clumps of trees. Once the vegetation has been cut and treated the remaining foliage may be burnt, left to decay or taken to a local landfill for proper disposal. It is not recommended to mulch Brazilian pepper trees for use in landscapes unless the tree is male or not in seed. Local foresters can provide information on burning permits and other local laws. Brazilian pepper belongs to the Anacardiaceae family; therefore the sap and smoke from the burning may irritate or cause an allergic reaction to sensitive individuals.

As with any control method, followup is important. Treatment areas must be checked periodically for new infestations or recurring growth from remaining stumps.

Herbicidal Control

Brazilian Pepper, like other woody plant species, can be controlled with herbicides applied in a variety of ways. The most common application methods are foliar spray, stump treatment, basal soil treatment, and basal bark application. Foliar treatments the herbicides are pre-mixed with diluent and sprayed onto the foliage of the plant. Usually the leaves are "sprayed-to-wet" which means applying only enough solution to begin running off the leaf surface. Basal soil treatments can be used with either liquid or dry formulations. The material is broadcast onto the soil under the canopy of the tree. Rainfall carries the herbicide into the root zone of the plant where it is absorbed by the roots. The basal bark application consists of the herbicide solution being applied, most commonly by back-pack sprayer, in a wide band on the stems of the plants near the base. The material is absorbed into the plant and translocated throughout the plant. Another technique is to treat the stump with a herbicide solution immediately after cutting the tree at or near ground level. There are other application methods such as the "frill and girdle", and various direct injection techniques for the control of exotic species. However, these methods are not practical for controlling Brazilian pepper. Aerial application of herbicides can be used in areas that are remote or where there are large monotypic stands. A complete description of these herbicide application techniques can be found the Exotic Woody Plant Control manual (Langeland, 1990).

Since the 1960s, various agencies have used available products to manage the growth and spread of Brazilian pepper. Prior to the establishment of the United States Environmental Protection Agency (EPA) this plant was controlled using SILVEX (2,4,5-TP) applied as a foliar treatment from truck-mounted sprayers. This was a chlorinated phenoxy herbicide in the same group of chemicals as 2,4-D. By the time EPA suspended all uses of SILVEX, circa 1976, the Velsicol Chemical Company had registered another phenoxy-type compound known as BANVEL 720 (dicamba plus 2,4-D) for use on woody species. In the early 1980s other compounds such as triclopyr, glyphosate, hexazinone, tebuthiuron, and imazapyr were being developed for managing vegetation on rights-of-way. The South Florida Water Management District (SFWMD) provided field trial sites for these compounds during and after their development process. Although data collected from these trials were not published, most of these products provided 95% - 100% control of Brazilian Pepper when applied in accordance with label directions.

In the early 1980s, several studies were done to determine which herbicides and rates are most effective for Brazilian pepper infestations. Woodall (1982), working at the USDA Southeastern Forest Experiment Station, tested eight herbicides at various rates in both greenhouse and field studies. He found that DED-WEED (2,4,5-TP), HYVAR (bromacil), KARMEX (diuron), TORDON (picloram plus 2,4-D), and VELPAR (hexazinone) provided 100% control of seedlings in the greenhouse study. AMMATE X (ammonium-sulfate), BANVEL (dicamba) and ROUNDUP (glyphosate) did not provide significant seedling control. In the field study basal soil treatments using HYVAR and VELPAR were effective in controlling Brazilian pepper trees. Results of foliar applications using DED-WEED, BANVEL, VELPAR, and AMMATE X (ammonium-sulfamate) proved variable at best (table 1).

Ewel et al., (1982) chose five products for field trials at Everglades National Park following an initial screening of potential herbicides. These included BANVEL 720, BANVEL 5G (dicamba), ROUNDUP, VELPAR and GARLON (triclopyr). Herbicides were applied in February and March. Results indicate that Brazilian pepper can be killed with a foliar application of triclopyr and glyphosate at high rates, basal bark treatments with triclopyr, and basal soil treatments with hexazinone. The two dicamba formulations were not effective (table 2). Ewel noted two reasons for a springtime application. First, low water levels increased accessibility and reduced environmental hazards associated with introducing herbicides to flooded soil. Second, herbicide uptake is greatest if applied when a plant is metabolically active. Male trees produce new leaves after the end of autumn flowering in November. Female trees do not resume new leaf production until fruit fall is completed in February/March. It should be noted that Woodall's study was conducted in late summer to late autumn as compared to Ewell's study which was conducted inFebruary and March. Based on later studies (Vandiver, 1993, personal communication), it is likely that timing of application is very important.

In studies conducted at Everglades National Park, Doren and Whiteaker (1990) showed that the basal bark application of GARLON 4 (triclopyr) at a 2% solution provided 94% control and that higher concentrations did not provide any significant increase in the amount of control obtained (table 3).

Laroche and Baker (1994) evaluated several herbicides and application techniques. Application techniques included foliar, basal bark, basal soil, and direct tree injection with E-Z-JECT capsules and FICSAN plugs. The established treatment plots were heavily infested with Brazilian pepper, generally very dense and consisting of numerous individual trees which were multi-stemmed. The corresponding treatment number of E-Z-JECT capsules were injected into the bark of each stem. The E-Z-JECT system uses a five-foot long, spring-loaded, telescoping barrel to inject 22-caliber cartridges into the bark of the tree. Each capsule is filled with a waxy formulation of herbicide which slowly melts with increased temperatures and is absorbed by the tree. In another treatment, FICSAN plugs were placed in small openings, created with a hollow-core tipped hammer, around the circumference of each stem. These plugs are made of plastic and are specially designed to rupture from the inside when hammered into the opening, releasing herbicide into the tree (Laroche, 1992). Foliar applications were made with a truck mounted sprayer. The appropriate amount of each herbicide was diluted in 50 gallons of water and the resulting solution was sprayed over the foliage with a handgun. Foliar applications were directed to each individual tree in each plot to minimize damage to non-target vegetation. Basal soil treatments were made with a backpack sprayer by applying the appropriate amount of undiluted herbicide on the soil around the base of each stem. SPIKE 40P (tebuthiuron) was also applied by hand-throwing the appropriate amount of pellets around the base of each tree. Basal bark applications were made with a backpack sprayer by applying the appropriate amount of herbicide directly onto the bark around the circumferance of each stem. The herbicide was diluted in diesel oil to facilitate penetration of the bark. All treatments were applied in March. The plots were evaluated one year post treatment and percent mortality or defoliation was used to determine the effect of each treatment (table 4).

Neither the E-Z-JECT or FISCAN plug treatments produced acceptable control levels. Herbicide symptoms were apparent in these treatments but none of the trees were defoliated. In addition these application techniques were cumbersome and difficult to use due to the density of the understory and multiple-stem growth habit of the trees. Foliar application of GARLON 3A and ARSENAL (imazapyr) resulted in greater than 90% control at both rates. RODEO (glyphosate), even at the higher rate, resulted in defoliation of only 32% of the trees. According to Vandiver (1993, personal communication) RODEO tends to be more effective on Brazilian pepper when applied in December in South Florida. Basal soil application of VELPAR and SPIKE were very effective. Basal bark application of GARLON 4 in an oil based solution is also very effective. The results of this study showed that site conditions and seasonal timing of application will determine the most effective combination of herbicide and method necessary to achieve good control of this pest plant. Since this study was done, VELPAR has lost its registration for use in wetland areas and can only be used in upland terrestrial sites and SPIKE is no longer registered in Florida. This is due to their persistence in the soil and potential for contamination of groundwater.

These studies indicate that several herbicides can effectively control Brazilian pepper. Generally, site conditions will often determine what combination of herbicide and method of application to use for the control of this pest plant in South Florida. Additionaly more research is necessary to further understand the relatonship between herbicide effectiveness and time of application.

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Table 1-Results of herbicide trials on Brazilian pepper conducted by Woodall (1982).

Herbicide	Rate	Method	% Cont.	Summary
AMMATE	.46kg a.i./Liter	Stump	43%	Stump treatments are suitable only whentops are required to be removed from the site. They give temporary control and are labor intensive.
BANVEL	.06kg a.i./Liter	Stump	90%	
DED-	.06kg	Stump	92%	

WEED	a.i./Liter			
VELPAR	4.5 kg a.i./ha	Broadcast-soil	95%	New seedling developped within 9 months, possibly originating from stored seeds as well as a new seed crop.
AMMATE	65kg a.i./1000 L	Foliar	0%	Due to the fact that foliar applications are a physiologically indirect means of killing root systems, the probability for long lasting success with this method is low - Brazilian Pepper is a vigorous, easily sprouting species.
BANVEL	1.2kg a.i./1000 L	Foliar	52%	
DED-WEED	4.8kg a.i./1000 L	Foliar	82%	
VELPAR	4.8kg a.i./1000 L	Foliar	75%	
VELPAR	8ml/ 5cm s.b.d.	Basal-soil	98%	For widely scattered bushes where access to the main stem is difficult, basal spot is easy effective and selective.
HYVAR	8ml/ 5cm s.b.d.	Basal-soil	98%	

Table 2-Results of herbicide trials on Brazilian pepper conducted by Ewell et al., (1982)

Herbicide	**Rate**	**Method**	**% Cont**	**Summary**
BANVEL 720 Liq.	5%	Foliar	58%	Malformed epicormic and basal sprouts were observed after defoliation following application, but most of these sprouts later died
BANVEL 720 Liq.	2.5%	Foliar	77%	
BANVEL 720 Invert	3.5%	Foliar	73%	
BANVEL 720 Invert	1.8%	Foliar	62%	
BANVEL 5G	48ml/m crown dm.	Soil	18%	Results were not readily visible until at least 2 months after application. This treatment was not effective even after 9 months following application.
BANVEL 5G	8ml/m crown dm.	Soil	8%	
ROUNDUP	1.7%	Foliar	54%	Recommended for large numbers of small individuals, as in the understory of a stand.
ROUNDUP	.8%	Foliar	100%	
VELPAR	24 g/L water	Foliar	100%	Killed >75% of the neighboring shrubs and vines, most of them were still dead 9 months post treatment.
VELPAR	12g/L water	Foliar	100%	
GARLON (M-4021)	.8%	Foliar	92%	Recommended for large numbers of small individuals, as in the understory of a stand.
GARLON (M-4021)	.3%	Foliar	77%	

GARLON (M-4021)	1.5%	Basal-Bark	100%	Had little long-term impact on understory plants. Recommended for killing large trees.
GARLON (M-4021)	.5%	Basal-Bark	100%	

Table 3-Results of herbicide trials on Brazilian pepper conducted by Doren and Witaker (1990).

Herbicide	**Rate**	**Method**	**% Cont.**	**Summary**
GARLON 4	2%	Basal Bark	94%	Very little difference in treatment effectiveness between the two concentrations.
GARLON 4	4%	Basal Bark	96%	See above.

Table 4-Results of herbicide trials on Brazilian pepper conducted by Laroche and Baker (1994).

METHOD*1*HERBICIDERATE%CONTROL

EZJECTRODEO1 capsule @ 2" intervals0%

RODEO 1 capsule @ 4" intervals0%

RODEO 1 capsule @ 8" intervals0%

FISCANSPIKE1 capsule @ 3" intervals0%

SPIKE 1 capsule @ 6" intervals0%

SPIKE 1 capsule @ 12" intervals0%

VELPAR 1 capsule @ 3" intervals0%

VELPAR 1 capsule @ 6" intervals0%

VELPAR1 capsule @ 12" intervals0%

Basal SoilSPIKE0.25 ounces / 6" BSD*2*98%

SPIKE 0.5 ounces / 6" BSD95%

SPIKE 1 ounce / 6" BSD97%

VELPAR 2 milli1iters / every 2" BSD40%

VELPAR 4 milli1iters / every 2" BSD84%

VELPAR 8 milli1iters / every 2" BSD91%

Basal BarkGARLON 4 1:4 oil @ 0.1 oz/ 1" BSD5%

GARLON 4 1:4 oil @ 0.25 oz/ 1" BSD10%

GARLON 4 1:4 oil @ 0.5 oz/ 1" BSD55%

FoliarARSENAL0.5% solution*3*95%

ARSENAL 1.0% solution98%

GARLON 3A 1.5% solution93%

GARLON 3A 3.0% solution97%

RODEO 0.5% solution0%

RODEO 1.5% solution55%

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1 EZJECT® Injection ammo is preformulated with an 83.5% formulation of Glyphosate, and FISCAN® Injection plugs are pre-formulated with a 90% formulation of hexazinone or an 80% formulation of thebutiron.

*2*BSD = Basal stem diameter

*3*Half a pint of X77 and 8oz of submerge was added to each 50 gallons of herbicide solution in all foliar tretment. Each Brazilian pepper tree in each plot was sprayed to wet.

Proposed and Enacted Laws

In Florida, widespread recognition of the severe threat posed by Brazilian pepper is evident in the many laws enacted throughout the state to prohibit the sale and cultivation of this plant. There is a state law prohibiting the sale, cultivation and transportation of Brazilian pepper (Appendix 1). In 1990, section 369.251, was passed by the Florida legislature. In 1993, 16C-52, Florida Administrative Code, was amended putting Brazilian pepper on the State's prohibited plant list.

Several counties restrict the sale , transportation or cultivation of melaleuca by law. many of these counties also control it by omission from tree protection ordinances or require removal upon site development. Some counties have permitting requirements before removal is allowed. The following counties have ordinances that prohibit the sale or require the removal of Brazilian pepper: Broward, Charlotte, Collier, Dade, Highlands, Hillsborough, Indian River, Lake, Lee, Manatee, Martin, Monroe, Palm Beach, Pinellas, Sarasota, Seminole, St. Lucie, Volusia.

Map

Resource Management Approach

The integrated management of Brazilian pepper requires a combination of control techniques to be effective. Essential elements of effective management include: biological, herbicidal, mechanical and physical control. Comprehensive descriptions for each of these management techniques are located in section xx

Prior to implementing Brazilian pepper controls the following factors must be considered and used in developing a site specific control plan:

1) Occurrence - extent of infestation, density, spatial distribution and other plant communities that are present.

2) Topography and soils - How does occurrence relate to elevation and soils? What are the characteristics of the soils - organic, sandy, hydric?

3) Hydrology - Has the site been impacted by drainage? Are there canals, agricultural fields, or wells nearby that may have caused a drawdown of the water table on the site?

4) Available management techniques - Which method of treatment or combination of methods is most suitable to the site being treated?

5) Economic factors - How much will it cost to exert initial control and then provide a long term follow up? What are sources of funding, grants, mitigation? Will the work be done by agency staff or by a contractor?

6) Public perception - Will public reaction cause bad publicity? What can be done to educate the public to avoid negative reaction?

7) Work schedule - Determine a reasonable time schedule as a goal for initial treatment and plan for routine maintenance control.

The key to an effective and long-lasting management program for Brazilian pepper is the introduction of biological control agents. Without biological control, Brazilian pepper elimination will be much more expensive and could not be truly integrated. The current investigation into biological organisms will most likely result in the introduction of defoliators and sprout inhibitors. Once introduced, several years are generally required for populations to build effective levels. In the interim, and throughout the biocontrol introduction phase, herbicidal and mechanical controls will be required to reduce current infestations and prevent spread into currently uninfested areas. Manual removal of seedlings in combination with single tree herbicide applications is the most conservative approach in natural areas. However, individual tree treatments are costly. Thus, less costly methods of herbicide application are currently being investigated. Direct herbicide application can still result in non-target damage, as much as a year after treatment, depending on the herbicide used. Aerial application of herbicides may result in less herbicide being used on a site and in some situations may lower the cost of initial treatment. Manual removal of seedlings may not be advisable in all situations due to the percentage of roots broken below the ground surface. In addition, the soil disturbance that results may stimulate more seeds to germinate. mechanical removal using heavy equipment is best suited for rights-of-way and other similar areas where routine maintenance follows and site disturbance is not a concern.

Case Studies

Big Cypress National Preserve

Background

Brazilian pepper is one of the most problematic exotic species in the Preserve. Brazilian pepper quickly invades disturbed, well-drained sites such as roadside soil banks, levees, oil well pads, old farm fields, and abandoned homesites, with the largest monotypic stands occurring on filled sites. In addition, scattered trees and small stands can be found in hardwood hammocks, as an understory plant in pinelands, and as an epiphyte on stumps and cypress knees.

Control Efforts

Herbicidal

Brazilian pepper control has been ongoing since the creation of the Preserve in 1974. Primary treatment methods have been basal treatments with 15% Garlon 4® using diesel fuel as a carrier or stump treatments using 100% Garlon 3a®. In 1994, a 150 gallon spray tank was purchased and a foliar spray program was initiated using Garlon 4® herbicide (2.5% solution) with water and Kinetic® added as a surfactant. This program was designed to reduce the seed source in an effort to minimize Brazilian pepper recruitment into surrounding natural areas.

Mechanical

Another facet of the National Park Service effort to eradicate Brazilian pepper from the Preserve relies on the use of heavy equipment. Prior to federal acquisition, lands within the Preserve were often used for activities that resulted in disturbance to the natural landscape. These lands were subject to rock mining, homesteads, farming, and road and canal construction. These human-caused changes to the landscape often resulted in the filling of wetlands. These filled areas are almost always heavily infested with Brazilian pepper.

Our strategy for eradicating the Brazilian pepper focused on its intolerance to extended inundation (Hilsenbeck, 1972, as cited in Duever, et al., 1986). Based on this premise, our plan for eradicating the Brazilian pepper from these areas focused on extending the hydroperiod by restoring the areas' elevations to predisturbance conditions.

Brazilian pepper was mechanically removed from the areas utilizing a bulldozer with a root rake. With the use of a track-hoe and bulldozer, the fill material was excavated and disposed of. The final elevations were determined by the presence of cap rock and/or the elevations of the surrounding areas. Monitoring of these sites has revealed no re-establishment by Brazilian pepper. To date, over 250 acres of Brazilian pepper have been removed.

Biscayne National Park

Brazilian pepper is less of a problem on the islands of the Park than other invasive pest plants such as *Colubrina asiatica* (Lather leaf), *Thespesia populne*a (Seaside mahoe) and *Schaevola taccada*. However, on the mainland, especially around Convoy Point, Brazilian pepper is becoming more widespread, particularly after Hurricane Andrew. A possible reason for this is the transport of copious seed material from the islands to the mainland by hurricane winds. The plant quickly colonized disturbed sites and, once established, spread to new areas. The areal extent of Brazilian pepper coverage in the Park today is unknown, and a mapping project is planned to provide this information.

Since Hurricane Andrew, exotic plant control in the Park has not been performed with any regularity. The resource managers of the Park are formulating an exotic plant management plan and hope to implement a major initiative soon. Documentation of control efforts will be required under the new plan.

Control Methods

The main method used for the treatment of Brazilian pepper in the Park is cut and spray using Garlon3A. Basal bark treatments using Garlon 4 are being planned. The latter treatment will be used on Brazilian pepper in the remote areas of the Park, while the cut and spray method will be applied on trees in high profile areas.

De Soto National Memorial

Background

Brazilian pepper is one of our most problematic exotic species in the Park. It is found in the Park's dense population of mangroves and in isolated areas adjacent to the Park. Mechanical removal of the pepper trees have had some effect, but, due to its increased spread throughout the Park, we have resorted to chemical control.

Control Efforts

The chemical control of Brazilian pepper is accomplished by applying triclopyr (Garlon 3A). This chemical is applied to fresh cut stumps 4" to 6" in length. It is applied with a hand pressure sprayer. Product use rate is applied at an undiluted or 1:1 mixture with water applied to the cambium. At DESO, we have found that applying it directly to the stump using 100% undiluted product is most useful. Our Brazilian pepper control program was initiated as of January 1994.

Everglades National Park

Background

Schinus terebinthifolius was first reported growing in a farmed area of the Park known a Hole-in-the-Donut in 1959 (Alexander & Crook, 1974) but probably became established there in the 1940's (Olmsted& Johnson, 1983). It began to spread throughout this area as these farmlands were abandoned. In the early 1960's, Craighead reported that Brazilian pepper had advanced around Everglades City. In 1972, after Hurricane Donna, Hilsenbeck found that the plant had invaded *Muhlenbergia* prairie and the mangrove zone near West Lake. Brazilian pepper distribution was mapped by Park resource management personnel in 1976 and found to have spread to parts of the pinelands, the Flamingo area, the coastal area around Madeira and Little Madeira Bays, and north of Park headquarters along the eastern Park boundary. An unpublished report by Koepp (1978) on the occurrence of *Casuarina* in the southeastern corner of the Park indicated its presence there as well.

A 1982 survey of Brazilian pepper in mangrove areas found that plants were discontinuously distributed and occurred in patches with certain habitats; i.e., low mangrove areas, being more susceptible to invasion than others (Olmsted & Johnson, 1983). The most recent information on Brazilian pepper distribution in the Park is derived from a Park mapping project using 1987 aerial photographs. This distribution map (Map 1) reveals an areal extent of Brazilian pepper in excess of 105,000 acres, 95% of which lies in the mangrove zone along the west and northwest coasts. Details on the mapping procedure are found in Rose (1988). Recent, cursory surveys in the East Everglades indicate that a number of tree islands; e.g., bayheads in Shark Slough, particularly those disturbed by dry season wildfires and, more recently, by Hurricane Andrew, are supporting increasing numbers of Brazilian pepper.

Management Strategy

The size and extent of Brazilian pepper populations in the Park defy control methods by available resources. The majority of the control effort--surveying, treatment, and monitoring, is carried out by rangers in the various districts of the Park. They are guided by annual "action plans" developed by districtbackcountry rangers in cooperation with Park resource managers. The control work carried out varies among the districts and is a reflection of differences in personnel, funding, and other work assignments.

Recent control efforts have concentrated on maintaining areas treated in past years. Flamingo District rangers have treated and maintained the area along the main Park road between West Lake and Mahogany Hammock and between East and Northwest Cape. Pine Island District rangers, with assistance from seasonal work crews, have maintained the Anhinga Trail at Royal Palm. Northwest District rangers (at Everglades City) have treated and maintained several backcountry campsites. The time devoted tt Brazilian pepper control is limited by the treatment of other Category I exotic pest plants including *Casuarina spp.* and *Colubrina asiati*ca which have established populations on the islands and shores of Florida Bay and the Gulf Coast.

Control methods

Herbicidal

The chemical control of Brazilian pepper in the Park is accomplished by applying trichlopyr (Garlon) as a basal bark or cut stump treatment. The basal bark formulation contains 4% - 8% mineral oil, while the cut stump formulation contains 50% water. Follow-up treatments are necessary to treat regrowth (sprouts). Small plants are pulled by hand or treated with a foliar application of Arsenal where the dilution and rate of application vary depending upon the formulation used.

Mechanical

The mechanical removal of mature Brazilian pepper from 3.5 acres on an upland site at Chekika Hammock in the East Everglades Acquisition Area was carried out in the fall of 1993 as part of a mitigation and restoration project. The Brazilian pepper trees were uprooted using heavy equipment, piledinto heaps, and mechanically mulched. The mulch was laced around the bases of native trees left standing in the cleared area; i.e., *Bursera simaruba* and *Ficus aurea*, creating a series of low maintenance beds 18 - 24 inches deep. Brazilian pepper recruitment in these beds is easily controlled by hand pulling.

The cleared area, however, consisting of three zones with varying elevational and hydroperiod patterns, necessitated that a different Brazilian pepper management strategy be used for each zone. One zone (shallow soil on higher ground) is managed to control the re-establishment of Brazilian pepper by regular mowing, thus hindering the establishment of woody vegetation. A second zone (long hydroperiod marsh) is revegetating naturally with typical wetland species; Brazilian pepper is controlled by the hand pulling of seedlings.

The third zone (intermediate in elevation and hydroperiod) was regarded as being most susceptible to Brazilian pepper colonization and was covered with sod (St. Augustine grass) as a temporary ground cover and weed deterrent. Brazilian pepper has not yet been found in this zone. This area will eventually be planted with subtropical hardwood species similar to those found in the adjacent hammock.

Hole-in-the-Donut Mitigation Project

Situated within the boundaries of the Park, the Hole-in-the-Donut (HID) comprises approximately 4,000 ha of previously farmed land. One-half of the area was rock-plowed, and, after its abandonment in the mid-1970's, the area has been invaded by Brazilian pepper (Map 1). The remaining 2,000 ha of non-rock plowed land, abandoned from 1930 through the early 1960's, has returned primarily to native vegetation with only a small portion dominated by Brazilian pepper (Ewel, et al., 1982).

When the Park acquired the HID in 1975, farming ceased, and restoration of the area was addressed. Several studies were carried out in the Park to examine old field succession. (See Doren, et al., 1990, for a summary.) However, the rapid spread and establishment of Brazilian pepper in the area, estimated at increasing by as much as twenty times its population density per year (Loope & Dunevitz, 1981), proved too overwhelming for successful restoration.

During the late 1970's and 1980's, several methods were tested to eliminate Brazilian pepper, including bulldozing, burning, mowing, and planting and seeding of native species, and all failed. However, one method, the complete removal of disturbed substrate, resulted in the recolonization of previously rock-plowed sites by native vegetation to the exclusion of Brazilian pepper. This has been attributed to the removal of the effects of the disturbed substrate and subsequent increase in hydroperiod (Doren, et al., 1990).

In 1989, through an off-site, compensatory mitigation project, funding was provided for a pilot project involving the experimental removal of the disturbed substrate on approximately 24 ha of degraded (previously rock-plowed) wetlands within the HID. On 18 ha of the site, Brazilian pepper was mechanically removed and the soil removed to bedrock, while on the remaining 6 ha, part of the soil was left after Brazilian pepper removal. Continuous monitoring has revealed that the larger site has successfully eliminated Brazilian pepper (and other pest plants) and restored native wetland species, while *Schinus* has recolonized the entire area of partial soil removal. This study and data from several other sites in Dade County indicate that the restoration of Brazilian pepper-dominated, rock-plowed wetlands are dependent upon the complete removal of the fundamental substrate; i.e., the artificially created substrate with concomitant hydrological improvements. Details of the pilot study are given in Doren, et al. (1990).

The apparent success of the pilot project has encouraged the Park to expand the work on a larger scale and reclaim all the remaining Brazilian pepper-dominated, rock-plowed wetlands within the HID. The Park has applied for a Federal Clean Water Act, Section 404, dredge and fill permit and a State of Florida wetland regulatory permit to establish a regional mitigation bank. It is estimated that the mechanical removal of Brazilian pepper (and subsequent substrate removal) from the entire 2,000 ha in the HID will take up to 20 years to complete. Work is scheduled to begin in late 1995.

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